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ABSTRACT

When developing curriculum materials for new contexts, designers feed forward work from similar projects. This customization process must attend to various influences to determine how features from previous efforts will be emphasized and combined. This paper discusses resources and ideas that influenced the design of the RiverWeb Water Quality Simulator (WQS), which has been used in biology and environmental science as well as in a special summer enrichment program emphasizing chemistry. Project staff investigated related materials, including various online notebook strategies and watershed modeling curricula from the University of Michigan. The paper describes how the WQS resulted from the combination of these ideas with the digital watershed concept developed at the National Center for Supercomputing Applications. Teachers may customize materials to more closely match their circumstances. The customization process for a Web-based simulation dictates a flexible architecture providing direct teacher modification such as addition of notebook questions and reorganization of resource links. In the Maryland Virtual High School Core Models Project, teacher leaders spent countless hours helping teachers do this, developing together, a more robust conceptual and pedagogical framework for the topic. The paper describes the nature of teachers' customization, which often reflected class level and discipline and local environmental features. Appended are computer screen print outs of the following program elements: WQS Map Page; WQS Graph Page: Station 0 Shown; Question Designated by "Location"; Question for Comparing Sediments within Stations 0 and 2; View of Question List by Teacher; and WQS Concept Map for Environmental Science. (Contains 11 references.) (SM)

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Customization in the Design and Implementation of the RiverWeb Water Quality Simulator (WQS)

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Abstract

When developing curriculum materials for new contexts, designers feed forward work from similar projects. This customization process must attend to a variety of influences to determine how features from previous efforts will be emphasized and combined. In this poster, we will discuss the resources and ideas that influenced the design of the RiverWeb Water Quality simulator, which has been used in biology and environmental science as well as in a special summer enrichment program emphasizing chemistry. Project staff investigated related materials, including various online notebook strategies developed by WISE and Covis and watershed modeling curricula from the University of Michigan (Bell, Davis, and Linn, 1995; Edelson and O'Neill, 1994; Stratford, Krajcik, and Soloway, 1998). We will describe how the WQS resulted from the combination of these ideas with the digital watershed concept developed at NCSA.

Teachers also customize materials to more closely match their circumstances. The customization process for a web based simulation dictates a flexible architecture providing direct teacher modification such as addition of notebook questions and reorganization of resource links. In the MVHS CoreModels Project, teacher leaders spent countless hours helping teachers do this, developing together a more robust conceptual and pedagogical framework for the topic. We will describe the nature of teachers' customization, which often reflected class level and discipline and local environmental features.

Introduction

Aims of Research

At its technical and scientific core, the RiverWeb Water Quality Simulator (WQS) consists of a web-based learning environment enabling students to investigate relationships between land use and water quality. The WQS has been deployed for research into self-regulated learning among students (Azevedo et al., 2001), pedagogic content knowledge support for teachers (Verona et al., 2001), and as a prototype for constructing a more generalized framework to develop web simulations enabling engaged learning in multiple areas of science (Verona, 2001). This paper investigates how development of the WQS benefited from similar water quality curriculum efforts and provides teachers with the ability to adapt use of the simulator to their particular curriculum goals.

The RiverWeb Water Quality Simulator (WQS) represents a first attempt by MVHS to create an extensive web learning environment. The WQS is a EOT-PACI (Education,

Outreach and Training Team of the Partnership for Advanced Computational Infrastructure) pilot project initiated through collaboration with National Center for Supercomputing Applications (NCSA). The simulator integrates modeling and visualization with exemplary, web-based learning materials linked to national and state standards. It includes a digital notebook that allows teachers to provide their own scaffolding and structure through directions, increasingly complex questions, and links to other resources.

In essence, the WQS represents the effects of various land uses on water quality in an archetypal watershed. By limiting each sub-watershed to one land use, the effect of that land use on can be seen on the quality of the water that students "test" within its boundaries. The cumulative effect of the combined land use determines the water quality shown by the indicator values found at the common outflow. After the user logs in, a map of the archetypal watershed appears (See Figure 1). Water quality monitoring stations located throughout the watershed are shown. The user may click on the map to investigate any sub-watershed. The RiverWeb graph window appears which by default displays the variation of nitrogen over time in the top window, and precipitation over time in the bottom window. As shown in Figure 2, other indicators may be selected, or the user might compare nitrogen concentration between two stations. In addition, reducing the day range for each graph provides the ability to zoom in on a particular time period. A scatter plot is available to further delineate the relationship of the pair of indicators or stations. A digital notebook link is keyed to questions related to the indicators currently selected. A tour option, which may be selected at log in, uses frames to combine the WQS with instructions leading the user through most of the simulator capabilities.

Inputs to the model include yearly time series of precipitation and air temperature observations. The program applies land use curves to the precipitation data to produce runoff. Additional land use curves utilize runoff to produce nutrient, sediment and toxin loads and concentrations. The most complex causal relationship involves dissolved oxygen, which depends on water temperature and nutrient load, which in turn depend on other factors.

As part of the Synergy Communities Aggregating Learning about Education (SCALE), WQS developers expect to continue to benefit from the experience of related projects. We will learn from the efforts of teachers working with these projects to adapt materials. In addition, we will learn from the work of MVHS teachers in integrating elements of these projects into their curriculum to support the WQS.

Influences on developing RiverWeb WQS

Many influences affected development of the RiverWeb WQS, in particular the examples of other watershed science curriculum and projects, including NCSA's RiverWeb initiative, and the prior experience of MVHS teachers and leader with the CoreModels Project, designated a "Promising Educational Technology Program" by the U.S. Department of Education Expert Panel. (US Department of Education, 2000; http://www.ed.gov/offices/OERI/ORAD/LTD/newtech_progs.html).

Various ideas from WISE (http://wise.berkeley.edu) influenced the design of the Water Quality Simulator – especially the student note capability. Like WISE notes, WQS student notebooks are available to teachers. Teachers request a WQS account that allows entry of distinct classes of students and student information.. Researchers also have access to student work. In addition, general characteristics of the WISE site design, of the WISE Strawberry Creek Activity, and especially ideas about evidenced-based reasoning has influenced development of the WQS.

MVHS leaders had experience in creating water quality models before investigating the research from the Center for Highly Interactive Computing in Education at the University of Michigan (hi-ce). But it was by understanding the learning experiences of middle school students using Model-It to explore local water quality issues (Stratford, 1996; Stratford, Krajcik, and Soloway, 1998) that we gained insights necessary for designing WQS learning activities. Since the development of the WQS prototype, hi-ce has made available an entire water quality curriculum that integrates modeling activities with field explorations and wet-labs (http://hi-ce.eecs.umich.edu/teacherworkroom/).

Exploring the Nardoo is CD-ROM-based interactive software designed for high school students and lower University levels and developed over three years by the Australian Department of Land and Water Conservation and the Interactive Learning Laboratory at the University of Wollongong. The cognitive goal informing software design is the development of students' investigation and problem-solving skills. Students address complex water management issues affecting the fictional Nardoo River. To do this they compare the same section of the river in its pristine condition in the 1900s and following development in the 1990s. Students note ecological differences due to the impacts of urbanization, farming, and industry; changes in water quality and chemical composition; and the evolution of fauna and flora. Using the software tools, they obtain "field data"; analyze that data using built in simulators; and access the built-in Water Research Center to utilize reference materials and seek the assistance of "experienced mentors."

Previous MVHS Projects

The first involvement of MVHS with water quality activities developed after issuing a 1996 request for teachers to design and lead collaborative Internet projects. Cecil County high school teacher Don Shaffer who has been instrumental in conceptualizing and implementing the WQS, responded by asking other teachers to add to his online water quality database. His classes had conducted water quality investigations of Maryland's North East River for years. Other schools adopted Shaffer's protocol and used a web form to add water quality measurements of local watersheds to the database. At a special stream workshop in November 1996, teacher participants used Calculator Based Laboratories (CBL's) to process stream samples and submitted their analysis through the project web form. Teachers used linear regression and curve fitting functions to find the mathematical relationships between several of the stream parameters. These equations were then used to build a part of a stream project simulation using STELLA. Teachers later reported that students were very enthusiastic about using CBL probes to collect

stream data. The probes, which permit the checking of dissolved oxygen or pH in several parts of the stream, invite deeper investigation than more traditional methods.

When the MVHS CoreModels project began in 1997, teacher Don Shaffer continued his interest in water quality modeling by developing a more complex stream model. He created the initial stream model during his work with the first MVHS project, but it took him an additional 18 months to design student worksheets that other teachers could use successfully in the classroom. Development of a teacher's guide took even longer. Since the beginning of CoreModels, he has coordinated biology materials development and continued to revise a core group of biology materials based on his own classroom experiences as well as feedback from the supporting teachers and new participating teachers. The algorithms for the WQS, originally based on Shaffer's model, have been modified to integrate dynamic water cycle relationships.

NCSA RiverWeb℠ Digital River Basin

Initiated by National Center for Supercomputing Applications or NCSA (link->http://www.ncsa.uiuc.edu), the lead organization for the National Computational Science Alliance, the RiverWeb Program (link -> http://theriverweb.org) leverages emerging modeling, simulation, visualization and web technologies to facilitate engaged learning about river basin processes among diverse audiences. RiverWeb's broad goals are to promote science-based, citizen and stakeholder participation in watershed management and policy, and to bridge environmental research with education, formal with informal learning, and government with citizenry. In the informal learning arena, the NSF-funded Mississippi RiverWeb Museum Consortium is utilizing science-based data, tools and methodologies, in particularly computer-based simulation and data visualization, to develop and deploy a suite of museum- and web-based *digital river basin* (DRB) exhibits at the Science Museum of Minnesota, the St. Louis Science Center, and the Illinois State Museum. A DRB is functionally defined as a digital exploratorium in which vivid, dynamic, digital representations of river systems and processes can be investigated over varying spatial and time scales through novel display and interaction environments, accessible from museums, classrooms and the web. The WQS represents a web-based DRB designed to support both structured and open exploration in formal settings such as classrooms.

CoreModels experience with teacher customization

In the MVHS CoreModels project, teachers worked with teacher leaders to develop packets that included STELLA models, student guides, and teacher background information for implementing modeling activities within science classrooms. Not only did activity developers try to create flexible materials, for instance by indicating sections teachers could omit if they were strapped for time, but the developers also included tips for adapting activities to basic or advanced classes, different lab situations, etc. Nevertheless, several activity units required repeated revision. Oftentimes this was done in a coordinated way under the direction of a subject area leader. Other times, however, materials were revised as an "individualized" activity for a particular class, level, or for an individual teacher's instructional goals. Typically such individualization took place as a teacher leader guided a less experienced colleague in preparation for upcoming

classroom modeling sessions.. The Central Region Center Director especially, favored teacher involvement in the process of individualizing activity design over standardization.

Some teachers also revised materials on their own and contributed them back to the group. Keeping track of multiple versions posed an administrative problem. Some subject area leaders became concerned that both approaches to customization resulted in a "dumbing down" of activities, a concern that will need to be addressed when scaling up modeling activities within and between larger numbers of classrooms. One way to understand this problem is to distinguish between a design project, where developers work with teachers in revising materials, and an implementation project, where teachers adapt materials on their own (Verona, 2002; Songer, 2002).

Friedmand and Culp (2001) described several key factors contributed to the success of the CoreModels Project. Theses included the close-knit, peer-to-peer structure of the CoreModels community and the presence of a core group of relatively senior and especially dedicated teachers, i.e. teacher leaders, who were able to act as a vanguard in exploring the pedagogic value of student-driven model construction and open-ended inquiry into systems. Especially important for the materials adaptation and customization process were first, CoreModels's sustained, long-term commitment to curriculum development, testing and revision, and second, its open structure, which allowed teachers to adapt and adopt modeling curricula for their own particular classrooms.

While these twin factors have led to CoreModels teachers' high level of ownership over their curriculum and classroom activities, they also point to a tension between how materials developers and implementers view the scaling up process. On the one hand, MVHS leaders want to disseminate their activities to a broader population of teachers while ensuring that the activities retain the qualities that made them successful. On the other hand, we know that successful adoption critically depends on effective professional development, which works best when conducted locally. Once again, the CoreModels Project offers points to ways to resolve this tension. CoreModels teachers are part of a community of practice. They may follow an activity designed by others, but they learn along with their students and feed back their understanding of the successes and difficulties that occurred, so that others can benefit from their experience. They may create an activity for others to use, but do so as part of and accountable to a community of peers who collaborate in reviewing their work. The same peer to peer characteristics will be needed for successful large-scale local adoption or adaptation of WQS and analogous system exploration activities To maximize such bi-directional information flow, the MVHS community is creating a Web Based Simulation and Collaborative Materials Development Environment (WebSim/CMDE).

Web Based Simulations (WebSims) allow easier customization

Since its inception, the MVHS CoreModels Program has developed over thirty activity packets, consisting of model, teachers guide, and student worksheets. Teachers need a more timely, interactive, and cost-effective mechanism for collaboration. In addition, we want to build on the initial MVHS vision to create a rich learning space for students, where classes may take part in stimulating online activities – collaborating with peers in the same room or school, or even in a different state. Commercial online services and vendors now routinely support collaborative, web-mediated processes somewhat similar to those we initiated five years ago.

We envision a portal that features web accessible simulations, supplementary learning materials for teachers and students, a student notebook, and communication tools for teachers and students. To be adaptable to a variety of circumstances, such a WebSim/CMDE environment must be easy to modify and extend. Building this portal involves 1) creating and piloting an initial exemplary web based learning environment with an online simulation as the hub and 2) formulating the strategies and tools to empower teachers to create similar exemplary learning environments around web simulations.

A WebSim consists of a series of simulation pages enhanced with a scaffolding approach that restricts variable manipulation and helps students connect their ideas to the simulation output thus making their thinking visible (Linn and Hsi, 2000, p. 74). Pages are generated dynamically via a server-based simulator. Each page includes an area on the left presenting abbreviated directions and providing form input. The main area is used for graphical output of the simulation, with a description at the top of the page. Links on the page allow access to the digital notebook, background information, text data output and supplementary graphs.

MVHS envisions the WebSims/CMDE project as a development environment in which teachers can propose activity modifications, review others' ideas, field-test activities with their students, and participate in decisions regarding the version to be released for public use. This on-line collaborative development environment will result in more teachers' views and insights being shared, and more classrooms testing the modifications. The team will use an analysis of student assessments and notebook responses to evaluate the effectiveness of the WebSim with respect to specific learning goals. Understanding gained from classroom use and assessment of student work will drive changes in the simulation activity pages so that teachers will have confidence in the ongoing educational value of WebSims for their students. Connections to national goals and adoption of pedagogical strategies such as the use of pivotal cases (Linn and Hsi, 2000) and questions which help students connect graphical output to real world behavior will be emphasized.

There are two important features of the WebSim/CMDE vision: the fact that online activity is focused around a simulation scaffolded to provide guided inquiry, and the fact that teachers will co-develop this scaffolding through the collaborative online environment. Without these features, the project is just another online educational

worksheet. MVHS will create the CMDE in response to compelling community needs; in particular, the need a method to encourage and manage the strands of activity modification that our sixty plus high school science teachers have taken on. In addition, there is a need to support teachers in a variety of professional roles, including that of materials development. The CMDE will also provide a mechanism for review by additional teachers and by scientists, as well as efficient materials revision or redesign.

Fostering customization using the WQS

Mary Ellen Verona and Don Shaffer designed the WQS in early 2000. It was quickly prototyped and first used with an Advanced Placement Environmental Science class in May 2000. It now serves as one of three prototypic WebSims that are informing our development of the WebSims/CMDE. The most important customization feature built into the WQS is a web form-based tool that enables teachers to select questions for the digital notebook from banks of existing questions, to adapt these questions, and to add their own questions to a database. For each question added, information is stored so that it appears when the student accesses the notebook from a corresponding graph page displayed in response to the chosen inputs. To build a network of conceptually related questions, teachers first need to determine which system relationships are relevant to their particular class. They do this by reviewing pertinent online (currently static) concept maps and then noting the relationships they want to emphasize.

Software features encouraging customization

The archetypal watershed depicted in the WQS allows teachers to relate a range of land uses to the local classroom or school environment. For example, a teacher in one location might want to emphasize the effect of agriculture on water quality, while a teacher in another location might want to emphasize the effect of urban pollution. How this might be done will be discussed below, once we have elaborated on how notebook questions are tied to particular land uses and indicators.

The WQS graph page provides for comparison of the changes over time of two indicators for one land use or of one indicator across two land uses. The WebSim notebook database has been constructed to allow indexing of notebook questions by the number and value of key words depending on the particular web simulation. For the WQS, notebook questions are indexed for a graph page by each indicator and land use area. Thus, when students click on the notebook link on a particular graph page, they are presented with the relevant questions (and instructions). Six different land use areas (in addition to pristine forest and river mouth) and a score of indicators are provided and support any number of investigative scenarios for individual student teams and classes (See figures 3-5).

Based on knowledge of their students' prior understandings, teachers determine how much to guide students in deciding which relationships to investigate, and when. In one instructional paradigm we have experimented with, the teacher first selects student land use groups in which students work together to conduct an initial exploration of the water quality in their sub-watershed. Then the teacher applies the Jigsaw cooperative learning technique, where students reform as expert groups tasked with investigating how and why and a selected indicator varies across the watershed. Finally, students reform within

their original land use groups and use the information gathered by each student in proposing recommendations to a hypothetical planning commission or civic council for improving water quality within their area and across the watershed.

Encouraging WQS customization – features not yet built in

When RiverWeb was introduced to teachers during the summer of 2000, they worked together to develop partial concept maps that were supported both by the evidence of the indicator graphs and by the concepts central to their teaching of water resource and water quality issues. These teachers requested that complete and scientifically sound concept maps be developed as part of the teacher support materials. During the past two school years previous such maps have been refined, but this is still a work in progress. Currently, two different versions of one fairly complete map exist. Each map includes two types of relationships: those supported by evidence from the WQS; and those that are important for the overall understanding of watershed processes but requiring the support of outside evidence. One version was recently adapted to meet the needs of environmental science teachers (see figure 6). A second concept map was adapted by and for Earth science teachers.

Thus, the choice of concept map features may be customized to match the course taught and a teacher's specific classroom needs. Disseminating existing maps allows for easy adaptation by environmental and Earth science teachers. In choosing to emphasize additional concepts, de-emphasize featured concepts, or add additional supporting relationships, teachers can further customize the WQS to meet their individual needs, and those of their students.

Once teachers have considered the importance of particular concepts and relationships they can determine areas for database question adaptation and development. Our goal is that customization of concept maps will spur and guide development of entire banks of notebook questions appropriate to different subject areas and specific types of student investigations. Teachers will then have the information they need to select between entire question banks, or to choose questions from within one or several banks, or to add their own questions.

Already several banks of questions have been created. Two versions were used by University of Maryland cognitive researchers in studying teacher-defined learning goals versus student generated sub-goals. A third version was developed for an honors biology class.

In an ideal scenario, teachers would team up to add additional questions that help students in exploring specific relationships emphasized on a previously customized concept map. For example questions about the covariation of water temperature and dissolved oxygen (a relationship that can be determined through the WQS) would be indexed by key words water temperature, dissolved oxygen, and the land use desired. Note that although saturated dissolved oxygen and biological oxygen demand are intervening variables, the teachers involved in the environmental science concept map decided that these concepts were not necessary for their students to develop a basic understanding of the physico-chemical process underlying the variation of dissolved

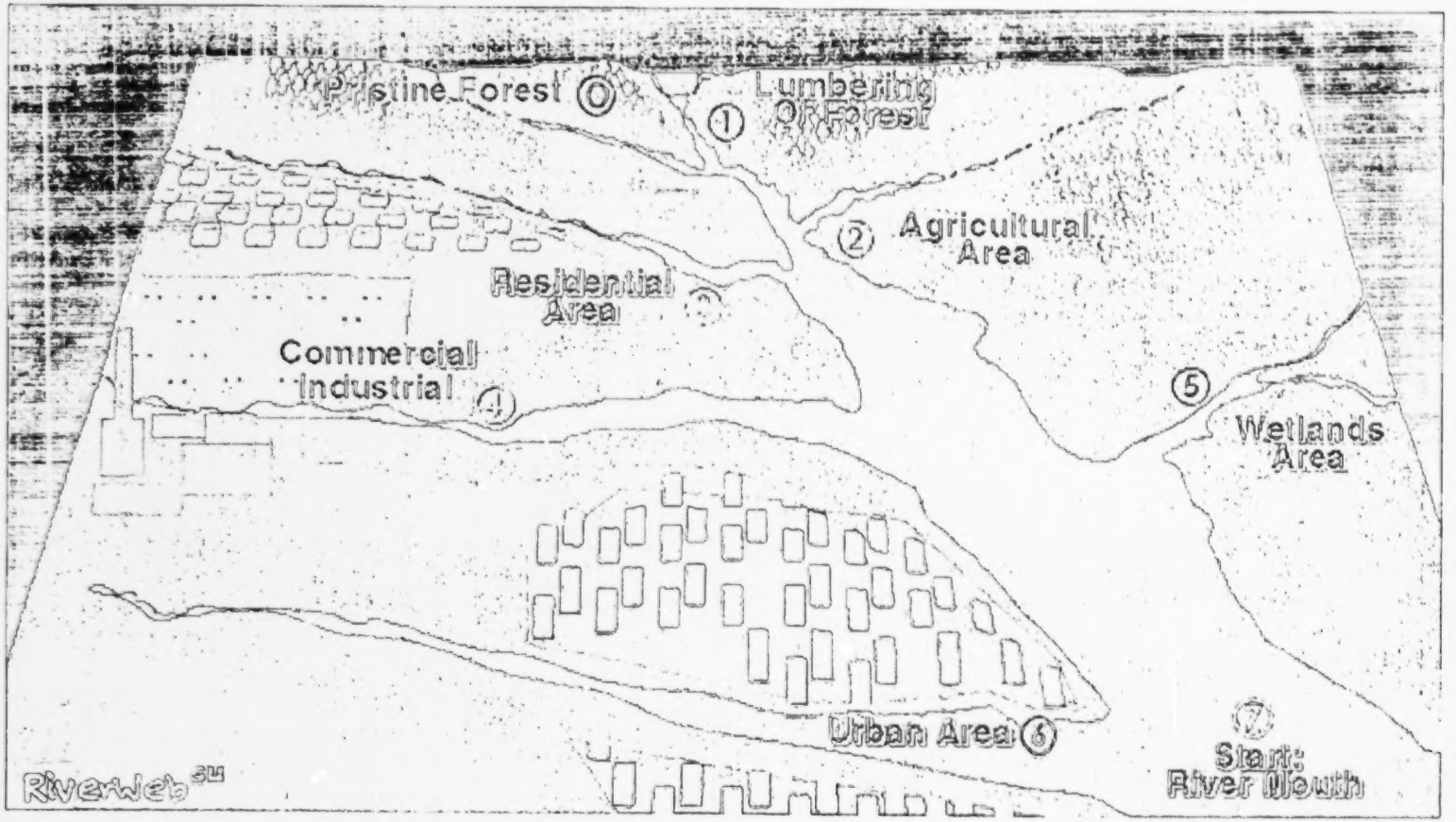
oxygen with temperature. A question asking why nutrients such as phosphates might affect dissolved oxygen cannot totally be answered through evidence from the WQS. The fact that a relationship exists may be determined by the WQS, but students must use resources and draw on their previous learning to determine missing links in the causality chain. Further versions of concept maps for teachers will be annotated with tips and information for obtaining supporting evidence for the relationship depicted. Links between causal factors supported by evidence provided by the WQS may be depicted as solid, with dashed links denoting other types of relationships. A key will also be provided for accessing external evidence on the web to investigate these relationships.

In the present WQS prototype, links to such web resources are made available on student pages. Additional links to web resources are available on teacher pages. Teachers may choose to permit their students to access these resources. Teachers may require or discourage use of particular informational resources, depending on their instructional strategy. Not surprisingly, many teachers we have worked with have requested that they be able to customize the classroom experience by editing the resources made accessible to their students.

Conclusion

Cognitively, the goal in developing the Water Quality Simulator is to help students create a more accurate mental model from the simulator investigation. The concept maps customized by teachers in designing their student's WQS learning experience are not given to the student in advance. Rather, the concept map in turn guides the teacher's development of a layered series of questions and instructions that scaffold the students as they explore the relationships incorporated in the map. Pedagogically, therefore, the he goal is for students to create their own schema of the relationships between physical quantities, land use and water quality. Students work individually and in-groups to flesh out their own concept maps of selected relationships within the WQS. To facilitate this we hope eventually to incorporate a concept mapping tool into the WQS learning environment.

For customization to work in practice, i.e. to scale, it needs to be carried out in keeping with principles of participatory design. WebSim/CMDE is precisely about that, and using information technology to support participation. The WQS can be viewed as an experiment in which the dimensions of the "problem space" of customization (or teacher-focused individualization of activities and materials) are being investigated.



WQS Map Page

Click to select land use area

Riverweb

Description: Pristine Forest 5000 acres
Present Status: n/a
Suggested Improvement: None

Top Display:
Select a Station

0 ◉ 1 ○ 2 ○ 3 ○
4 ○ 5 ○ 6 ○ 7 ○

Select Indicator

Nitrogen

Day 1 to 36

Range to

Bottom Display:
Select a Station

0 ◉ 1 ○ 2 ○ 3 ○
4 ○ 5 ○ 6 ○ 7 ○

Select Indicator

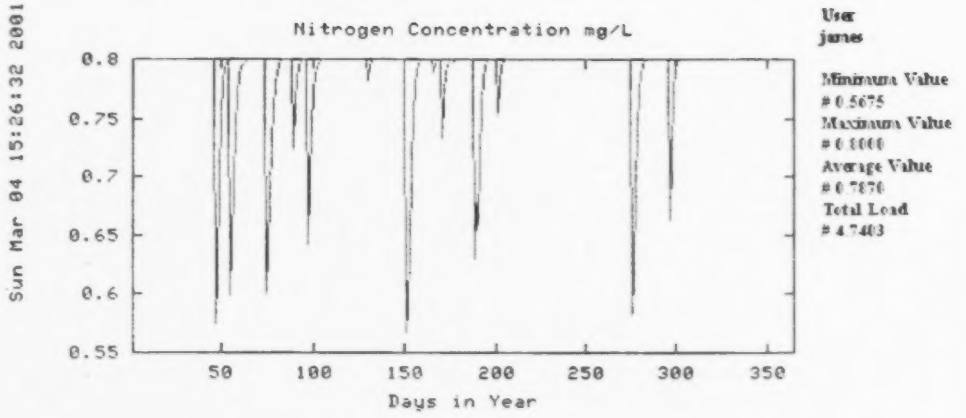
Precipitation

Day 1 to 36

Range to

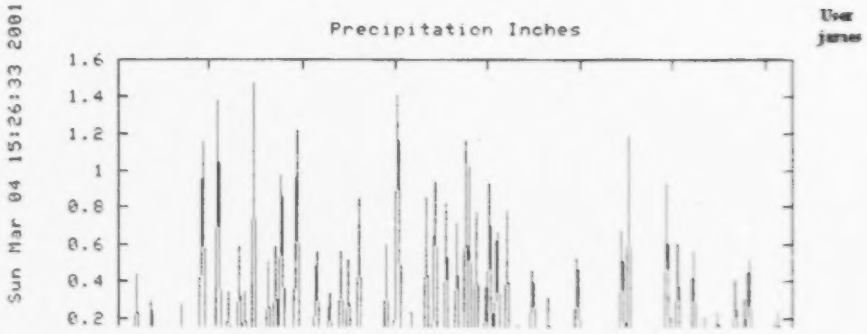
Change Display

Display Assessment
Display Map

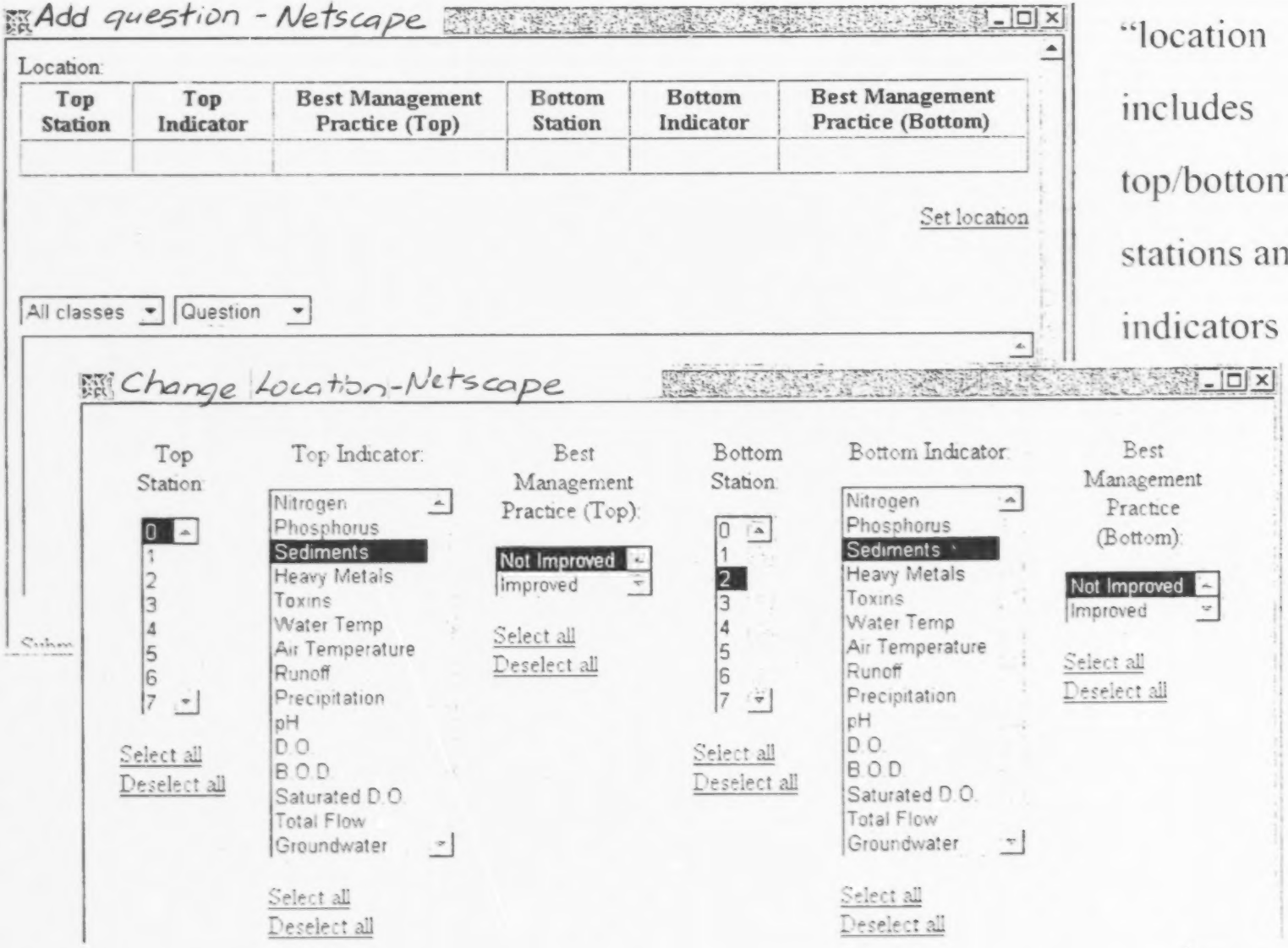


View pre-implementation Data

Station 0: Precipitation (Inches)



WQS Graph Page: Station 0 shown



"location includes top/bottom stations and indicators

Question is designated by "location"

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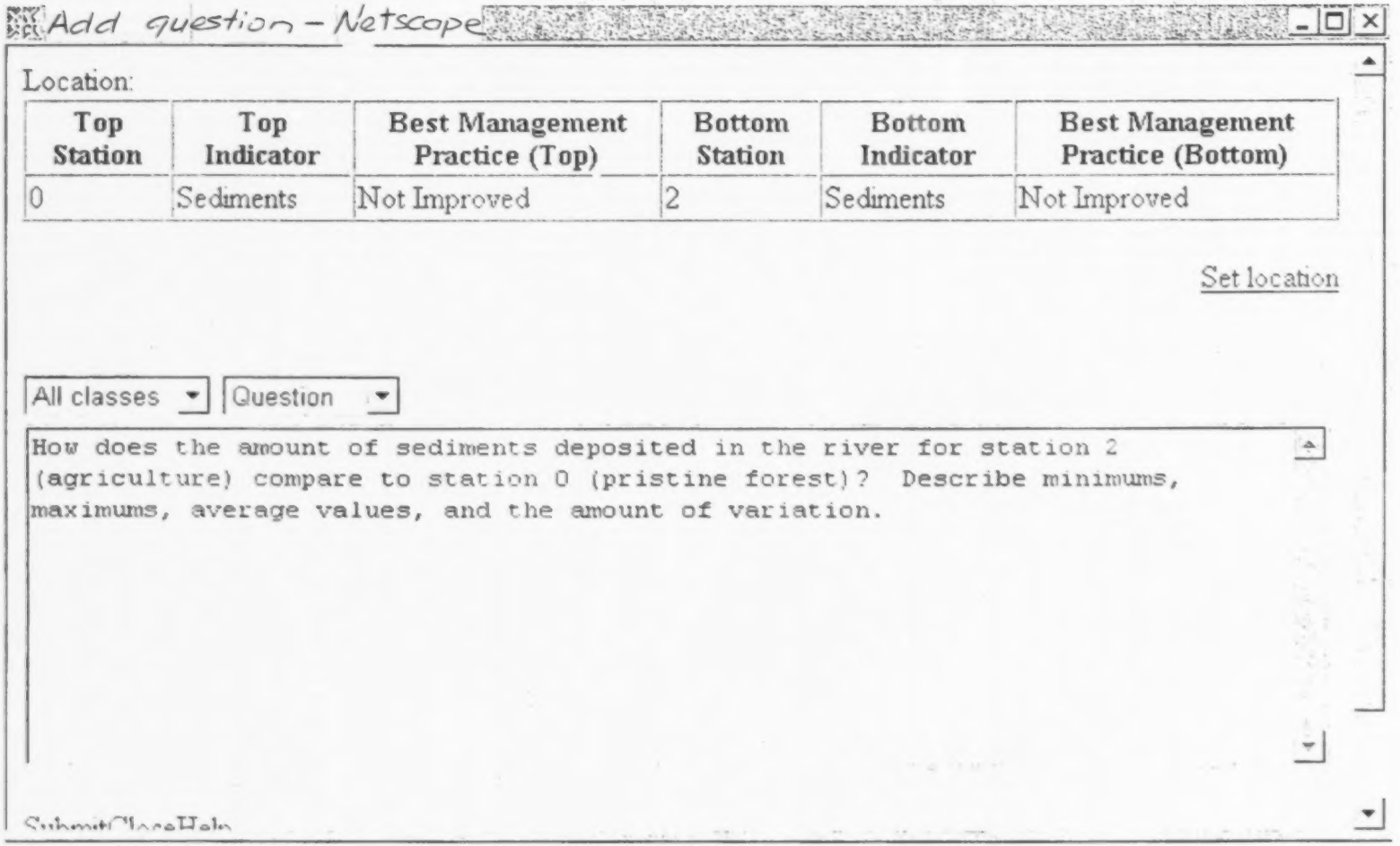

Question for comparing sediments within stations 0 and 2

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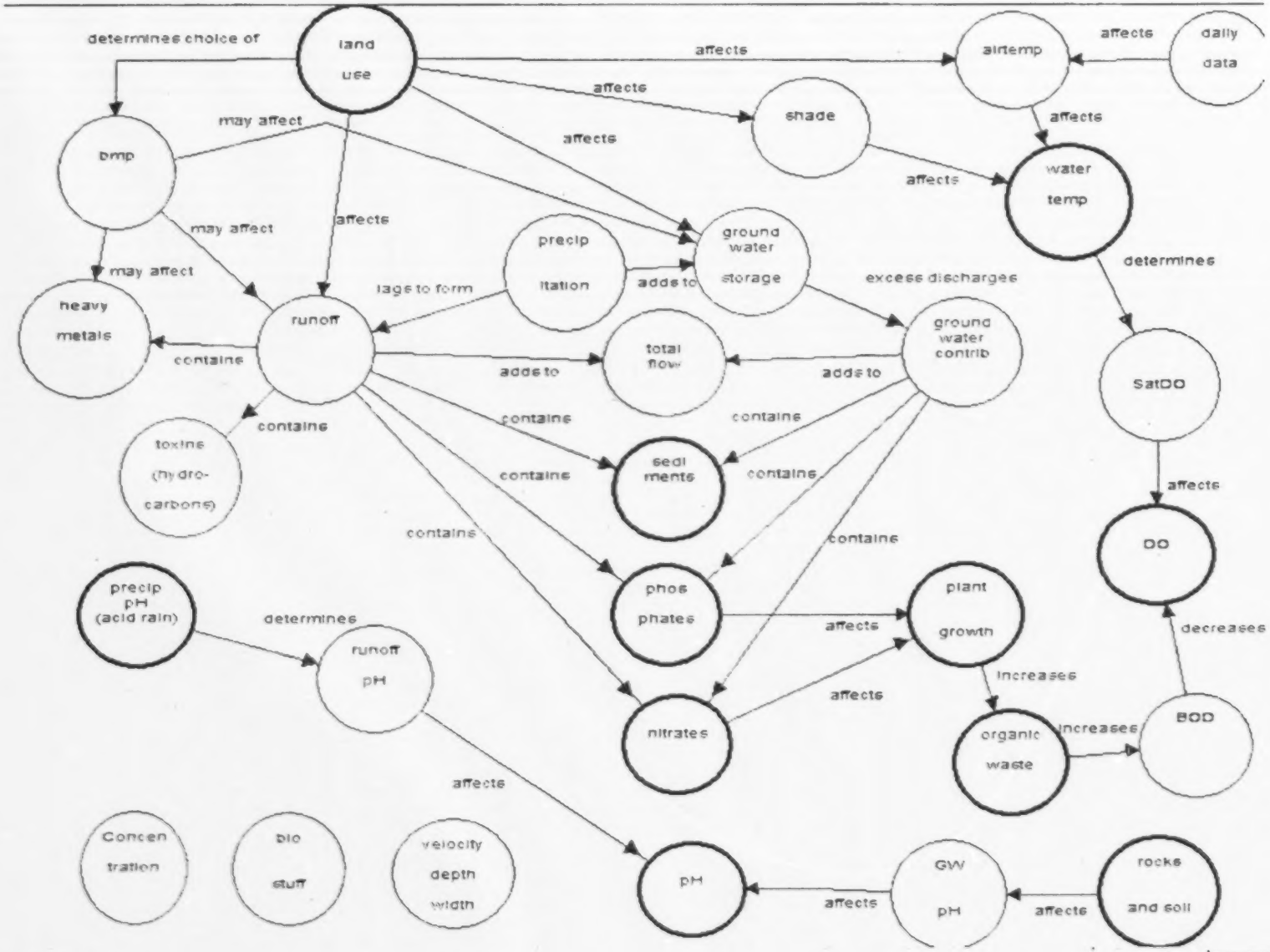
Viewing As ibarnes (Teacher)

View All Questions

Write New QuestionPrintHelp

Type	Text	Location	Action
Your question for class *All Students*	Explain the relationship (if any) between Phosphorus and dissolved oxygen shows by the graphs. Try restricting the range or using the scatter plot to get a better view. If you think there is a relationship, explain why a nutrients such as phosphorus might affect dissolved oxygen. If you think there is no relationship, hypothesize reasons for the structure of the dissolved oxygen graph.	**Top Station**: 2 · **Top Indicator**: Phosphorus · **Best Management Practice (Top)**: Not Improved · **Bottom Station**: 2 · **Bottom Indicator**: DO · **Best Management Practice (Bottom)**: Not Improved	Edit
Your question for class *All Students*	How does the amount of sediments deposited in the river for station 2 (agriculture) compare to station 0 (pristine forest)? Describe minimums, maximums,	**Top Station**: 0 · **Top Indicator**: Sediments · **Best Management Practice (Top)**: Not Improved · **Bottom Station**: 2 · **Bottom Indicator**: Sediments · **Best Management Practice (Bottom)**: Not Improved	Edit

View of question list by teacher



WQS Concept Map for Environmental Science

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